

SCIENCE FOR PEOPLE

Vigyan Prasar and NCSTC (The National Council for Science & Technology Communication) are organisational partners in many a science popularisation project in recent years. According to an arrangement worked out between the two organisations, Vigyan Prasar is responsible for distribution and dissemination of all science popularisation software developed and/or produced by NCSTC. In addition, Vigyan Prasar develops and produces its own science communication software, including CD ROMs, audio cassettes, slide sets, and activity kits.

SOME POPULAR TITLES OF VIGYAN PRASAR INCLUDE:

1. *Leaf Zoo (Hindi-English) Rs.20.00*
2. *Pumps from the Dump(Hin-Eng) Rs.20.00*
3. *Toy Joy (Hin-Eng) Rs.20.00*
4. *Let's Put Things Together(Hin-Eng) Rs.25.00*
5. *Seeing is not Always Believing (Hin-Eng) Rs.65.00*
6. *Rahu Ketu Ki Khoj (Hin) Rs.12.00*
7. *Khoya Hua Janam Din (Hin) Rs.20.00*
8. *Myths and Legends Related to Eclipse (Hin-Eng) Rs.21.00*
9. *Total Solar Eclipse: Answers to all your Questions (Hin-Eng) Rs.12.00*
10. *Hello Stars Rs.45.00*
11. *The Bicycle Story Rs.25.00*
12. *The Story of Physics(in comic strip, Hin-Eng) Rs.40.00*
13. *Chamarkar Ka Rahasya(Hin) Rs.25.00*
14. *Iodine Sainik (Hin) Rs.35.00*
15. *Gilas Se Khel Karke Dekho (Hin) Rs.25.00*
16. *Fun & Science at Home Rs.75.00*
17. *The Rustless Wonder: A Study of the Iron Pillar at Delhi Rs.350.00*
18. *Where Gods Come Alive: A Monograph on the Bronze Icons of South India Rs.350.00*
19. *Memoirs of Ruchi Ram Sahni: Pioneer of Science Popularisation' in Punjab Rs.350.0*

For orders and enquiries please write to: **The Director**
Vigyan prasar, C-24, Qutab Institutional Area, New Delhi 110 016
Phone: +91-11-6864157, 6967532,6864022, Fax: +91-11-6865986
e-mail: vigyan@hub.nic.in

Visit our Home Page: <http://www.vigyanprasar.com>

Diversity

– the cornerstone of life

Dr. Madhav Gadgil



Edited by Bittu Sahgal
NCSTC-HORNBILL
NATURAL HISTORY SERIES





Jointly published by:

Vigyan Prasara
C-24, Qutab Institutional Area
New Delhi 110 016
email: vigyan@hub.nic.in

&

Sanctuary Magazine
602, Maker Chambers V,
Nariman Point, Mumbai 400 021
email: bitu@viasbm01.vsnl.net.in

Text © *National Council for Science and Technology Communication*
and *Bombay Natural History Society*
Photographs: © *Sanctuary Photo Library*

All rights reserved. Students and researchers may use parts of this manuscript for projects and for other such non-commercial, educational purposes, provided the source and author are duly acknowledged.

ISBN 81-7480-026-3

NCSTC-HORNBILL Natural History Series

First Impression: 1997
Second Impression: 2002

Rs. 55/-

Printed at Saurabh Print-O-Pack, Noida

Diversity

– *the cornerstone of life*

This is an account of the manner in which nature has conspired to create diverse life forms and how these life forms have become the foundation of life as we know it.

For several years now the author, *Dr. Madhav Gadgil*, has dedicated himself to the proposition that science belongs to the people and must continually therefore be presented in a language that everyone can understand. This book is a testament to that commitment. His story starts with the cosmic Big Bang that is reputed to have triggered life on earth and carries on through to modern India where much of the diversity which had been preserved by our ancient culture has now been lost.

The author is contactable at

*The Centre for Ecological Sciences &
Jawaharlal Nehru Centre for Advanced Scientific Research,
Indian Institute of Science,
Bangalore 560 012,
email: <madhav@jnc.iisc.ernet.in>*

**NCSTC-HORNBILL
NATURAL HISTORY SERIES**

Rashtriya Vigyan Evam Prodyogiki Sanchar Parishad (National Council for Science & Technology Communications) is an apex body set up with the objectives of popularizing science and technology, stimulating scientific temper and developing scientific capability amongst the people. In order to fulfill these objectives the Parishad supports:

- Research and development in the area of S&T communication for devising more effective communication methods, tools and technologies;
- Software development in the form of films, radio and television programmes and popular S&T books and science magazines in different languages;
- Training of competent science communicators through short and long term courses in selected S&T based voluntary organizations and Universities;
- Recognition of outstanding communicators and institutions involved in S&T popularization through fellowships and awards;
- Field projects involving other science based agencies and local communities in the form of jathas, melas, science exhibitions, seminars, etc., and
- International cooperation with developed and developing countries.

More information is available from:

Head, RVPSP,

Department of Science & Technology,
Technology Bhavan, New Mehrauli Road,
New Delhi-110 016, INDIA
Phone No. (0)11 6866675 FAX: (0) 11 6960207

List of Plates and illustrations

(not to scale)

1. The Atom	xii
2. Bat in flight © Thakur Dalip Singh	3
3. Anemones and fungi	4
4. The building blocks of life	7-9
5. Tree of life	13
6. Life's progress	14
7. Space of life	18
8. Growing diversity	20
9. The lion	21
10. Competition for light (trees)	22
11. Size and diversity	23
12. Periyar Tiger Reserve © Suresh Elamon	31
13. Tiger skin © Dr. Anwaruddin Choudhury	32
14. <i>Impatiens nilagirica</i> © T. Chhabra	34
15. The species scape	37
16. Hotspots of diversity	39
17. The wealth of nations	41
18. Fitful progress	43
19. Diversity threatened	47
20. Spider's web and a beehive	49
21. Domestic fowl	50
22. Nurturing diversity	51
23. Sacred sites	52
24. Sanskrit etchings and hand painting	53
25. Totems of respect	54
26. Coastline wealth	58

Contents
Diversity
– the cornerstone of life
Dr. Madhav Gadgil

Editor's note	viii
Publisher's preface	ix
The cosmic dance	1
Dynamic earth	2
Molecules of life	18
Self-replication	10
Expanding biosphere	12
New ways of life	15
Quickening pace	18
Competition for survival	19
Mutual aid	24
Packing species	25
Species turnover	26
Diversity within a species	27
Diversity across species	35
Hotspots of diversity	38
A country of megadiversity	40
Spasms of extinction	44
Agents of destruction	48
The conservation ethic	52
India's genius	54
Sources	56
Index	60

Editor's Note

The Bombay Natural History Society (BNHS) has been a fount of knowledge for over a century. It has created and nurtured thousands of naturalists from all walks of life. Today the Society continues to add to the body of information gathered by all-time greats such as R.W. Burton, E.P. Gee, J.B. S. Haldane and, of course, Dr. Salim Ali, the 'Grand Old Man of Ornithology.' Long before the subject of environment had become fashionable; before the word biodiversity had even been coined, the study of nature was a mission for hundreds of BNHS members. In time this enduring institution gave birth to an amazing network of amateur naturalists. Their prime joy, apart from tramping India's wilds, has always been to share their experiences, knowledge and information about nature with others.

It is in this context that the production of the NCSTC-HORN-BILL series should be viewed. India is losing its natural wealth at a frightening pace and it is vital that decision-makers are exposed to the very real value of the ecological assets being lost to the nation. It is equally important that the rationale for wildlife conservation is understood. Humans, for instance, do not possess the technology to re-create the millions of hectares of natural forests, grasslands and wetlands we lose each year.

To maintain and to enhance the green mantle, which protects our soils and our water sources, we need the elephant to transport mango seeds. We also need chital to carry grasses from one part of the forest to the other as we do the tiny leaf warbler's non-toxic 'pest control' contribution. The cleaning service performed by turtles and crocodiles, frogs and the larvae of dragonflies helps make the water in our lakes and rivers drinkable. Every creature on Planet Earth performs a useful ecological role... save for *Homo sapiens*.

We probably started out right, but our capacity for abstract thought, our intellect and our relatively recent penchant for

consumerism, have lulled us into the mistaken belief that we can escape the consequences of the grievous damage we inflict on ecosystems and species. With each forest we lose, each river we degrade, each mangrove and coastline ecosystem we alter, the viability of the Indian subcontinent to sustain future Indians is diminished. Simultaneously the quality of life of perhaps over 100 million earth-people: among them, fisherfolk, forest dwellers, nomads and pastoralists... is lowered and their security compromised.

This latter aspect of the environmental and wildlife movements has only just begun to assert itself in our national psyche. Young people everywhere, social activists and human rights groups are fast recognising that protecting forests for the tiger, rhino and elephant automatically serves to protect both forest cultures and resources for communities which live outside the market system.

In the coming days this new partnership between naturalists and earth-people is destined to play a vital role in defending wild India. The author, Dr. Madhav Gadgil is an ideal link between 'ecosystem people' and the 'establishment'. He writes with knowledge and sensitivity about our dependence on natural ecosystems and the great need to restore our lost diversity. If the *NCSTC-Hornbill Natural History Series* manages to enhance the ecological information base of such initiatives and to replace pure sentimentalism with pragmatism in the battle to save nature... our purpose will have been admirably served.

*Bittu Sahgal, Editor
NCSTC-Hornbill Natural History Series*

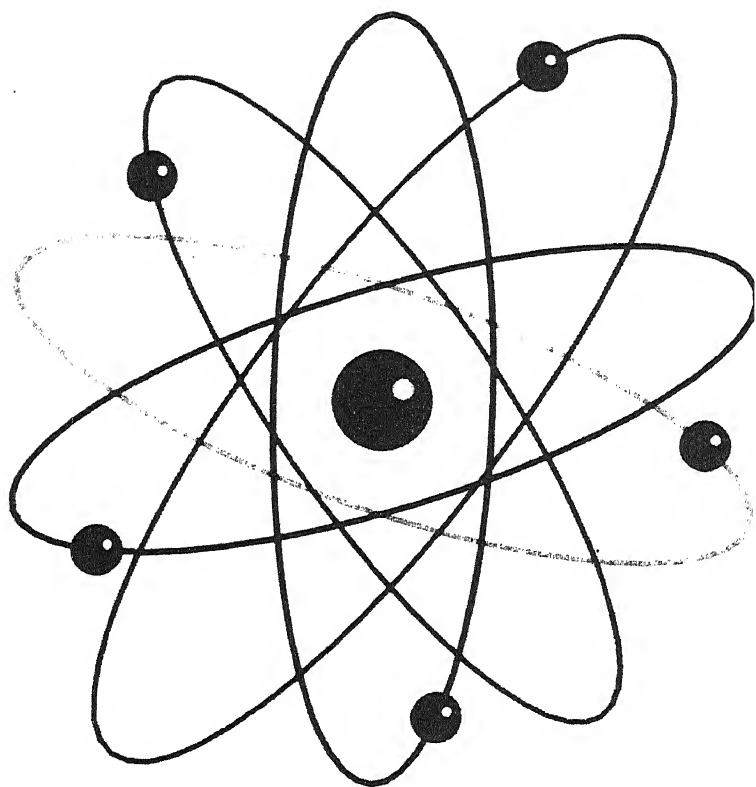
Publisher's Preface

This is one of a series of booklets that have been in the making for years! The wait has been worth it... both in terms of the contents and the fact that we have been able to win the involvement of the most authoritative authors on the various subjects chosen for the titles in the National Council for Science and Technology Communication, *NCSTC-HORNBILL Natural History Series*. NCSTC and the Bombay Natural History Society (BNHS) joined hands to bring the science of natural history to young people though adults too are sure to relate to the style and straightforward presentation. We intend to produce more titles each year to cover as wide a spectrum of nature as possible. We expect the publications to serve the dual purpose of disseminating information and keeping an archival record on the eve of the next millenium.

We wish to demystify the subject of ecology... to make it both understandable and acceptable to India's future decision-makers. The inter-relationships, the complex webs of existence, the contentious and confusing environmental issues... all these will need to be understood and grappled with by tomorrow's citizens. To the extent possible we have stayed away from scientific jargon for obvious reasons. We did not wish this initiative to be reduced to an isolated 'lesson' of the kind one often sees being taught in our schools and colleges.

In this book you will be introduced to the subject of diversity, the cornerstone of life on earth. Dr. Madhav Gadgil is one of our most respected and forward-thinking scientists. He takes us along a journey from the Cosmic Dance through conservation... to the genius that is India. We trust that this (and the other titles in the series) will encourage readers to search for the larger picture, the totality of inter-relationships... and thus aspire towards a better understanding of our own role on this planet.

*Dr. Narender Sehgal, Series Publisher,
Director Vigyan Prasar, June 5, 1997*



Cosmic dance

The world around us is a kaleidoscope of ever changing patterns. Patterns that change with the time of the day and the season of the year. Patterns that change from place to place. Patterns that have been in flux ever since the cosmos originated with a big bang fifteen billion years ago. In the beginning was pure energy concentrated in an infinitesimally small space. As the cosmos expanded, matter began to crystallize out of this cauldron. First as tiny elementary particles, each on its own, dancing separately. As things cooled down, the particles linked arms to form atoms. Initially smaller ones like hydrogen, helium, and oxygen. With time these atoms began to form complex molecules like those of water. Matter also came together to form larger atoms such as of iron and nickel, and larger complexes like crystals and metals.

Slowly matter condensed to form heavenly bodies; nebulae, stars, planets, meteorites. All the while atoms were bumping into each other, linking together to form more and more complex molecules. Of all the variety of atoms, carbon and silicon are the best at holding hands with each other, and with those of other kinds as well.

Like Brahma and Vishnu, our gods of creation and preservation, carbon and silicon have four arms each. So not only can they form long carbon or silicon chains, but a variety of side chains, with hydrogen, oxygen, nitrogen, even iron or manganese. The chains so formed can twist and wrap around each other, forming balls with a multitude of projections and indentations. Thus is formed an incredible diversity of carbon containing organic molecules. Molecules predominantly composed of silicon tend to form more regular sheets and three-dimensional structures, giving rise to particles of clay and crystals of quartz.

But atoms can hold hands with each other only when the surroundings are cool enough. When things heat up they de-link, preferring to dance, so to speak, on their own. At extreme temperatures they even lose their shells of electrons – the tiny particles that whirl around the nucleus of each atom. As a result a large variety of carbon containing molecules can only be formed at moderate temperatures, indeed at just such temperatures as we enjoy at the surface of the earth. It is not that the rest of the cosmos has no organic molecules; indeed there are some even in the wide-open spaces between the stars. Some rather large organic molecules also occur on meteorites called carbonaceous chondrites. But the planet earth has in abundance one other substance that has made all the difference. And this is liquid water.

***“When things
heat up atoms
de-link, prefer-
ring to dance, so
to speak, on
their own.”***

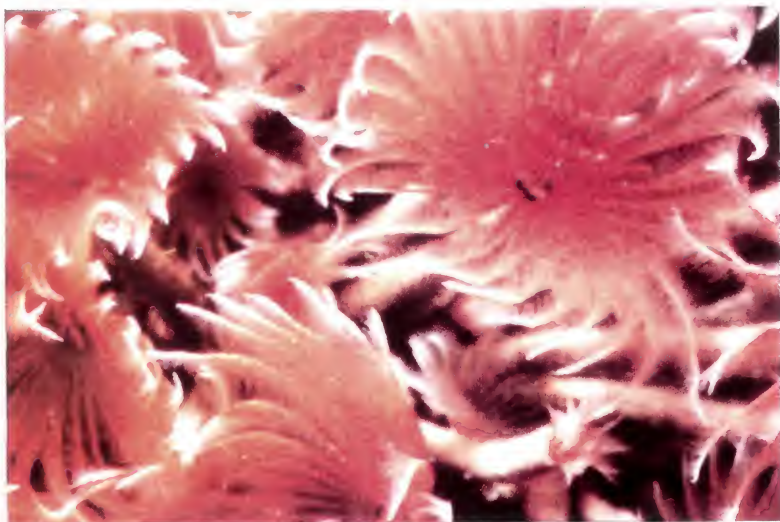
Organic molecules dance most joyously when immersed in water. Then they can really twist and turn, taking on a myriad shapes. They can really play with each other then, zipping and unzipping chains, chopping off a piece here, adding on another there. Swimming in water, the organic molecules let themselves go, eventually coming together to form the truly marvellous structures that living organisms are. Life owes its origin then to the great good fortune that on the surface of the earth prevail temperatures that permit water to remain for much of the time in its liquid form.

Dynamic earth

The earth on which this dance of organic molecules is in progress, is itself a dynamic entity. Water here is forever in flux, passing between its liquid and vapour forms; giving rise to clouds and rain, rivers and seas. The seas today cover more than two thirds of



Bats are the only flying mammals in the world. Their contribution to the biodiversity of the earth cannot possibly be fully documented. Some estimates suggest that they could be responsible for seed dispersal of up to 40 per cent of all fruiting trees in some rain forests.



All life originated in the ancient seas where evolution prompted partnerships and associations of amazing complexity between creatures such as the orange anemone and other coral lifeforms. On land, fungi and a host of other 'converters' recycle organic matter to feed all the diverse creatures that have evolved over millions of years.

the earth's surface; seas that one imagines have been there a long, long time. Clouds on the other hand are evanescent. An average cloud survives no more than an hour or so; larger collections of clouds persist for, at most a few days.

But we now know that seas and islands, continents and mountains are themselves subject to change, albeit on a much slower time scale. For on the surface the continual barrage of rain and wind

“A dance of organic molecules is in progress on earth which too is dynamic.”

wears the land down; and the flux of hot molten rocks in the interior of the earth raises it back again. Even more significantly, this flux of hot molten rocks in the bowels of the earth drives around whole plates of land and ocean floor, so that continents go on forming, splitting, reforming, on a time scale of millions of years.

The rich kaleidoscope of the patterns of nature that we constantly witness all around us is, then, a dance of organic molecules, coupled with a dance of water molecules, in a theatre that is itself changing slowly but irrevocably... all the time. The patterns of dance have been changing all of the four and a half billion years that Planet Earth has been in existence. The pace of change quickened a little when life first appeared on the scene three and a half billion years ago. It accelerated further when life invaded land four hundred million years ago.

When the tool-using ancestors of human beings first appeared on the scene two million years ago, there were few reasons to believe that the world was getting set for a dramatic increase in the rate of change in the manifold patterns of nature. But that has come to pass and today humans are a dominant force governing the variegated mosaic of nature.

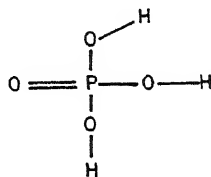
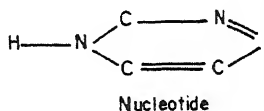
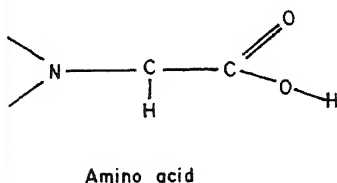
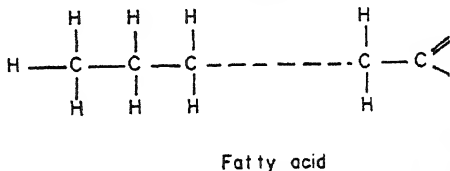
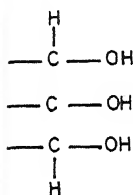
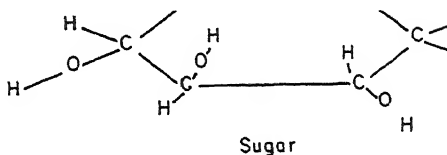
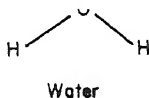
Molecules of life

The most fascinating, the most intricate, the most diverse of patterns in the world around us are the handiwork of living creatures including, of course, ourselves. This variety is fashioned out of what is initially a very small number, about 100, basic building blocks. Each of these is an organic molecule, with a backbone of carbon atoms randomly embellished by hydrogen, oxygen, nitrogen atoms. These building blocks are simple sugars, fats, vitamins, and most importantly amino acids and nucleotides. The last two are nitrogen-bearing molecules; amino acids, acidic in property and come in 20 different forms; the nucleotides, alkaline in property, come in five different forms. Now carbon has four arms with which to link, oxygen two, hydrogen only one. These are the most common constituents of organic molecules. Adding to these, nitrogen, with its three arms, brings an interesting element of asymmetry to the formations. These building blocks can of course be linked together to form larger, more complex formations. Thus proteins, in some ways the most vital of the larger molecules of life, are formed by linking together several amino acids in long chains. Now consider the great variety of such chains that may be formed by choosing one out of 20 amino acids in each position. With just two amino acids linked together there are 20×20 or 400 possibilities. With three 400×20 or 8,000, with four $8,000 \times 20$ or 1,60,000. Proteins in fact are made up of tens, if not hundreds of amino acids each, making possible millions upon millions of different combinations. The chains of proteins thus formed do not remain as long strings. They fold up, forming complex globular, ovoidal bodies. The shapes of these bodies are governed by the sequence of amino acids in the chain, so that

*“Carbon has
four arms with
which to link,
oxygen two,
hydrogen only
one.”*

The Building Blocks of Life

The magnificent diversity of life is based on the wide range of ways in which a small variety of building blocks may be put together. At the simplest level the building blocks are atoms, primarily of five elements, namely carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and phosphorus (P). The atoms of these five elements order in different ways to form the key molecules of life: water, sugars, glycerols, fatty acids, amino acids, nucleotides and phosphoric acid.



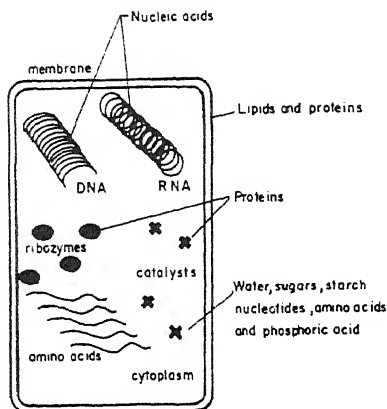


Fig. 1. Structure of a universal minimal cell (After Roberts, 1986): *Larger molecules of life are built up by putting together these building blocks: proteins from amino acids, lipids from glycerol and fatty acids, nucleic acids from nucleotides, sugars and phosphoric acid, starches and cellulose from sugars. These go to make up cells, the units of construction of all living creatures.*

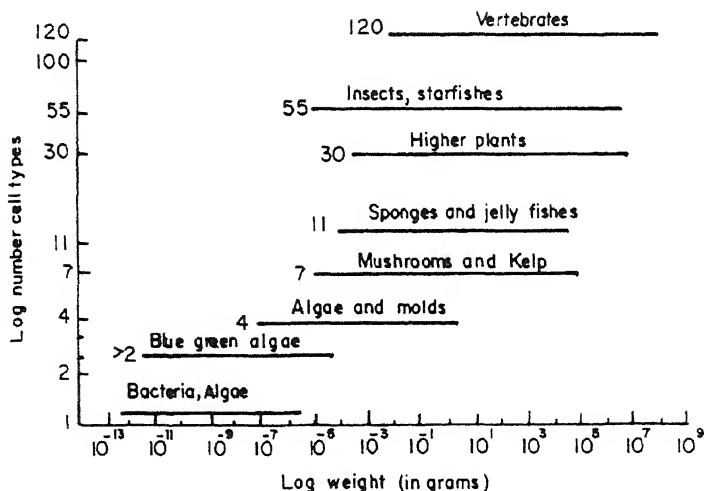


Fig. 2. A graph showing the size-ranges (by weight) of groups of organisms containing different numbers of cell types. (After Bonner, 1988): *The simplest organisms are made out of single cells. Some 50,000 species of single-celled organisms have so far been described, implying that subtle variations in the way cell constituents are put together can give rise to high levels of diversity. The more complex organisms are made up of multitudes of cells. The number of basic types of cells making up an organism increases with the size of the organism.*

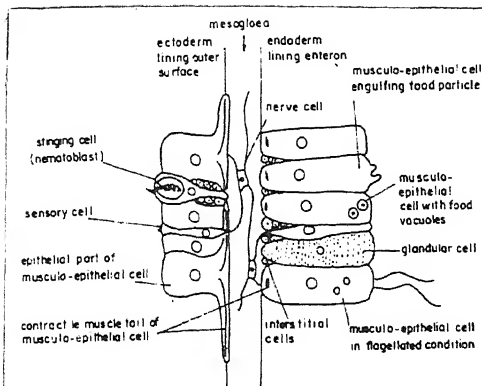


Fig. 3. A schematic representation of the construction of the body wall of the hydra. The hydra is one of the simplest of multicellular animals, around one mm. in size, living in fresh waters. (After Roberts, 1986)

Putting these basic cell types together in many different ways can create an endless variety of constructions.

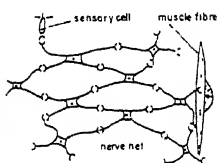


Fig. 4. Nerve net of a sea anemone (After Roberts, 1986): The diversity of living organisms is an outcome of the different ways of ordering and linking the variety of cells. The most intricate patterns of linkages amongst cells involve the nerve, sensory, muscle and gland cells. These range over simple nerve nets, such as in sea anemones, jellyfishes or hydra.

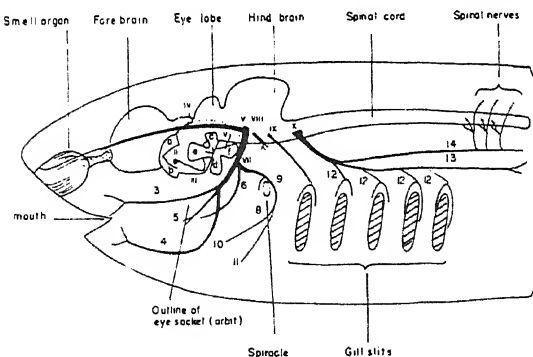


Fig. 5. The elaborate architecture of the vertebrate nervous system illustrated through the basic plan of the nervous system of a shark. (After Roberts, 1986)

Compared to other organisms, nerve cells make up a vastly greater proportion of the total number of cells in humans. Long periods of learning permit these nerve cells to link with other cells in a very flexible way. This is why human behaviour is so plastic and so variable. This is what has enabled us to dominate the earth and both destroy and value the diversity of life in a way no other animal can even remotely approach.

a whole variety of intricate shapes can be generated by just varying the order in which the amino acids are stacked one after another. And not only do these larger molecules come in many different, elaborate shapes, they also bear on their surfaces intricate patterns of positive and negative electrical charges.

Organic molecules with their myriad shapes and patterns of electrical charges can interact with each other in many different, and very specific ways. This brings within the realm of possibility the most important attribute of living organisms – the ability to fabricate more copies of themselves. This ability is grounded in the potential of complex organic molecules to take simple elements and then build them up bit by bit into complex molecules of very specific composition, shape and patterns of surface electric charges. In the course of their dance, after all, the actors are apt to break formations, forming all manners of patterns as a consequence of random charges. So much of the activity of life is the endeavour of complex organic molecules to resist their continual breakdown, and to keep building them back again. Reproduction is an extension of this enterprise, whereby whole copies of themselves are made.

“The most important attribute of a living thing is its ability to replicate itself.”

Self-replication

The enterprise of precise repairs and faithful copying has to be based in information. Organic molecules making up living organisms must have at their disposal instructions as to how to rebuild and fabricate other appropriate molecules. These instructions are set down in a special molecule that is as characteristic of life as the proteins: the molecule of nucleic acids. Nucleic acids are made up of nucleotides, along with sugars and phosphoric acid. The key to their information-carrying

ability lies in the nucleotides that come in five different forms. Any given organism has, however, only four of these. Nucleic acids have a backbone of long sequences of four kinds of nucleotides, wrapped around with sugars and phosphoric acid. Now just as we can have 400 (20×20) different sequences of a chain of two amino acids, or 8,000 ($20 \times 20 \times 20$) different sequences of a chain of three; we can have 16 (4×4) different sequences of a chain of two nucleotides, or 64 ($4 \times 4 \times 4$) different sequences of a chain of three nucleotides.

“The dance of life has become more elaborate, drawing on a larger number of actors.”

Since nucleic acid molecules have tens of thousands of nucleotides linked together, the potential for many different sequences is incredibly large. The instructions for sustaining and duplicating life are all stored in such sequences of nucleotides, and these instructions are passed on from one generation to the next of every living organism, forming the basis of heredity. Nucleic acids are therefore the stuff of which heredity is made – they are the genetic materials.

The wonderful dance of organic molecules that makes up life is then orchestrated through the elegantly simple device of stringing together four different kinds of nucleotides in many different sequences. And each of these four kinds of nucleotides is formed by just four different kinds of atoms; carbon, hydrogen, oxygen and nitrogen, all bonding with each other in subtly different ways. Triggered off in the hoary past three and half billion years ago, the dance of life has become more and more elaborate, drawing in an ever-larger number and variety of actors. And the stage on which they have been dancing has also continued to expand, beginning with shallow seas, invading depths of ocean, land, air and finally outer space.

Life's Progress

Full History of Life

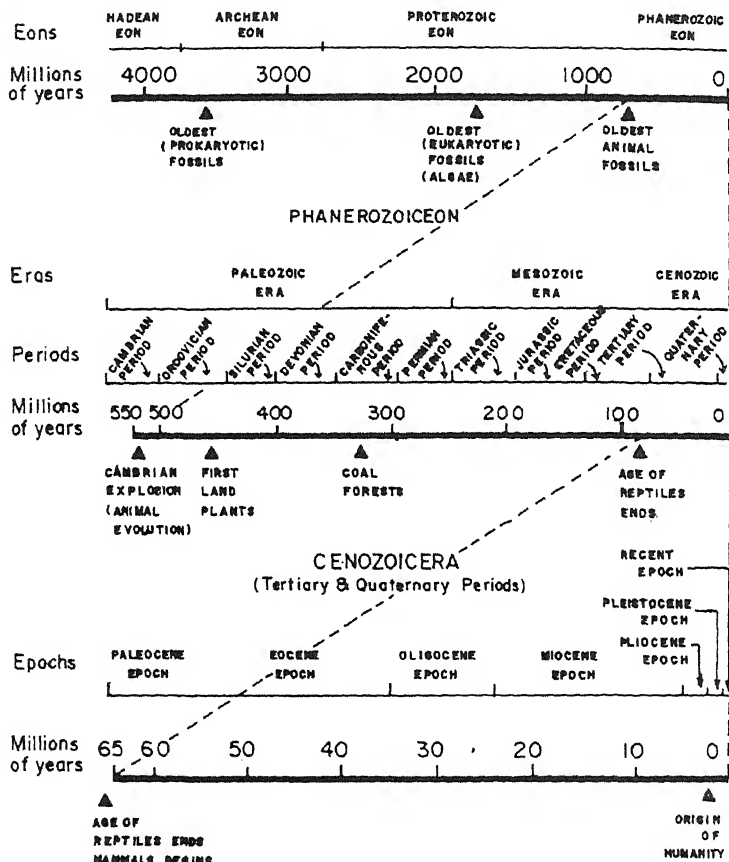


Fig. 7. The full geological history of life goes back more than 3.5 billion years, when the first single-cell organisms appeared. Key episodes in evolution are placed within the divisions of geological time: eons divided into eras, eras into periods, and periods into epochs. (After Wilson, 1992)

From these humble beginnings, life has continually invaded newer habitats, inventing more ways of dealing with the world around it. In this process of adjusting to new settings, living organisms have become increasingly complex. And finally, as these complex organisms have come to deal with their environments in new ways, they have become more diverse. Life, we saw, is but a highly orchestrated dance of organic molecules in a watery medium. It undoubtedly originated in water.

“Over time life has been able to invade almost every type of habitat on earth.”

It must also have originated in warm waters because the machinery of life performs best around 25^o to 30^o C.

It is likely to have originated at some depth, for the atmosphere of the early earth most probably let through a lot of ultraviolet light.

Too much of ultraviolet breaks up organic molecules. A column of water of 10 meters or so would, however, have effectively absorbed enough of ultraviolet to permit life to come into being. Life must have originated where reasonable concentrations of organic molecules would be built up; which is not likely out in the open ocean. Which is why we must presume that it was in shallow, warm seas that life first made its appearance.

Over time life has managed to invade almost every type of habitat on the earth, forever expanding the limits of the biosphere. Life is everywhere: out in the open ocean and in the deepest trenches in the ocean floor. It is in little pools in the Antarctic ice cap and in hot, sulphurous springs on land. It exists not only in the moister, warmer niches on land, but thrives in the driest of deserts and on cold mountain tops. It has taken to air, as pollen grains of flowering plants and spiders with their little balloons; as flying lizards gliding from tree to tree and birds flying from the Arctic to the Antarctic. This has of course happened in slow stages, over

billions of years. It has happened in small steps, with living organisms progressing to habitats more and more different from their ancestral home in the warm, shallow seas.

New ways of life

Living organisms have also taken to new ways of tapping resources. Every organism must necessarily maintain a flow of energy and materials through its body to keep itself going. Thus green plants absorb sun's rays and give out heat. Their roots take in water, which is lost through the leaves. The roots absorb nitrogen, phosphorus, potassium and molybdenum, which is eventually returned to earth with drying leaves and roots.

"Without exception every living thing must maintain a flux of energy-rich matter."

Animals feed on other plants or animals. They breathe in air and drink water. And then they excrete dung and urine, as well as breathe out air. Without exception, all living organisms must thus maintain a flux of energy or energy-rich matter through their bodies.

Living organisms have been elaborating increasingly complex ways of achieving this over their evolutionary history. The earliest organisms were born in an organic soup; so for them these organic molecules served as the energy source. They simply lapped up what had been formed through physical processes over the first billion years of earth history. We still have organisms that follow this route. They are bacteria and fungi that grow in rotting wood or in the corpses of animals.

These decomposers take in pre-formed organic molecules freely available in their surroundings. That was the only way of life practised for a long, long time; perhaps the first billion years. Over this period the supply of pre-formed organic molecules

perhaps began to run low. In any case, what developed were organisms that began to exploit an entirely new source of energy – that of sunlight.

These were the early green plants; in fact closely allied to bacteria, the blue green algae. With the help of their special pigments these creatures learnt to use sunlight to produce simple organic molecules from the abundantly available molecules of water and

“The machinery of early organisms could not, in fact, tolerate free oxygen.”

carbon dioxide. In the process of making sugar from carbon dioxide and water, they produced oxygen, as green plants do today.

For another billion or more years of evolutionary history simple green plants and decomposers existed on earth. But this environment was being radically transformed. In the beginning there was little free oxygen, either in the air, or dissolved in the water. The early organisms were in fact adapted to exist in an oxygen-free environment. For oxygen is a highly reactive element, rapidly combining with organic molecules. That after all is what happens when wood or a candle burns.

The machinery of early organisms could not, in fact, tolerate free oxygen. With it around, their organic molecules danced too madly, rushing to link themselves with oxygen atoms. But that did not keep plants with their green pigments from splitting off oxygen from water molecules to combine hydrogen atoms with carbon dioxide to produce sugars.

Thus the concentration of oxygen kept increasing in air and in the waters. Living organisms had no choice but to deal with the situation.

Quickening pace

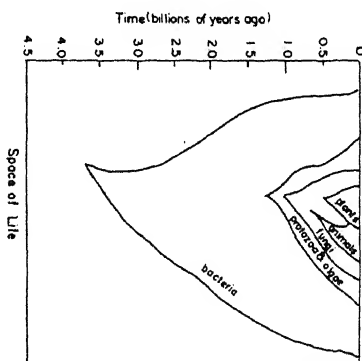
Initially living organisms evolved just to protect their molecules from combining too rapidly with the oxygen in the environment. But as oxygen concentrations went up, another more attractive possibility came to be exploited. This was to use the oxygen to speed up the flux of energy through the bodies of living organisms. This is what most organisms, including human beings do today. We eat energy-rich food, breathe in oxygen and use the oxygen to release the energy trapped in food molecules, use this energy to maintain our machinery in order, even to grow and reproduce. But this invention of using oxygen to facilitate energy fluxes came only after a long history, maybe of a billion-and-a-half to two billion years of evolution.

“The ability to use oxygen greatly quickened the pace of life on earth.”

The ability to use oxygen greatly quickened the pace of life. This added yet one more major way of life to the repertoire of living organisms. The oxygen-imbibing creatures could now take to actively feeding on other organisms. So along with decomposers

Space Of Life

Fig. 8. A great variety of complex organisms have come into being over the history of life with the later arrivals depending increasingly on organisms already present for their sustenance. The diagram represents the progressive appropriation of the total space of life by the later entrants on the evolutionary stage. (After Hawkesworth, 1992)



and photosynthesizers, the earth came to support organisms that grazed or preyed on others.

Decomposing, photosynthesizing, feeding on other organisms are the three broad ways of organizing the flux of energy necessary for all life. But living organisms have created an infinity of variations around these themes. Amongst green plants, for instance, are some who do well in bright, open light, while others

***“When creatures
tapped light
energy they
evolved pig-
ments like
chlorophyll.”***

thrive in the dim light of the forest floor.

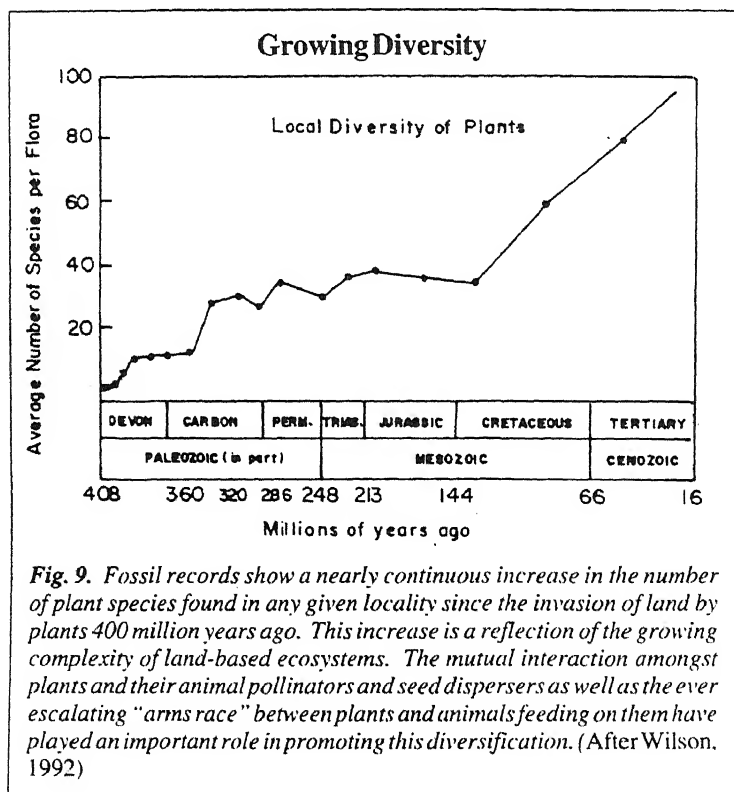
There are plants that grow well in swampy places and others that prefer the desert sand. Animals graze on grass or browse on leaves, burrow inside stems or gnaw on roots. There are predators that sit and wait for prey to be caught in their traps or webs, and others that pursue and run down prey.

There are parasites that live inside cells of other organisms, even becoming a part and parcel of their nucleic acids, and others that live in their guts or on their skin. And flowering plants reward insect pollinators with nectar for services rendered.

Competition for survival

As living organisms adopted these new ways of life and invaded an even greater range of habitats, they assumed increasingly larger sizes as well as more complex structures. Bacteria subsisting as decomposers on dead organic matter are amongst the simplest, smallest organisms. It has been but a small step for them to take to living inside bodies of other living organisms, feeding on living organic matter, without any great elaboration of structure. But when creatures took to tapping light energy, they had to produce special pigments, like chlorophyll. And they also had to elaborate protective structures as well as special chemicals or enzymes to

make sure that the oxygen released did no damage. Concentrating the chlorophyll in specially structured bodies further enhanced the efficiency of the process of photosynthesis. And then as plants invaded land, a whole range of new structures had to be formed to resist rapid loss of water and to fight gravity. So plants began to produce large quantities of tough yet flexible molecules of cellulose, so that cellulose is today the most abundant of molecules on earth. As plants became established on land they began to compete with each other for light and water. In more humid



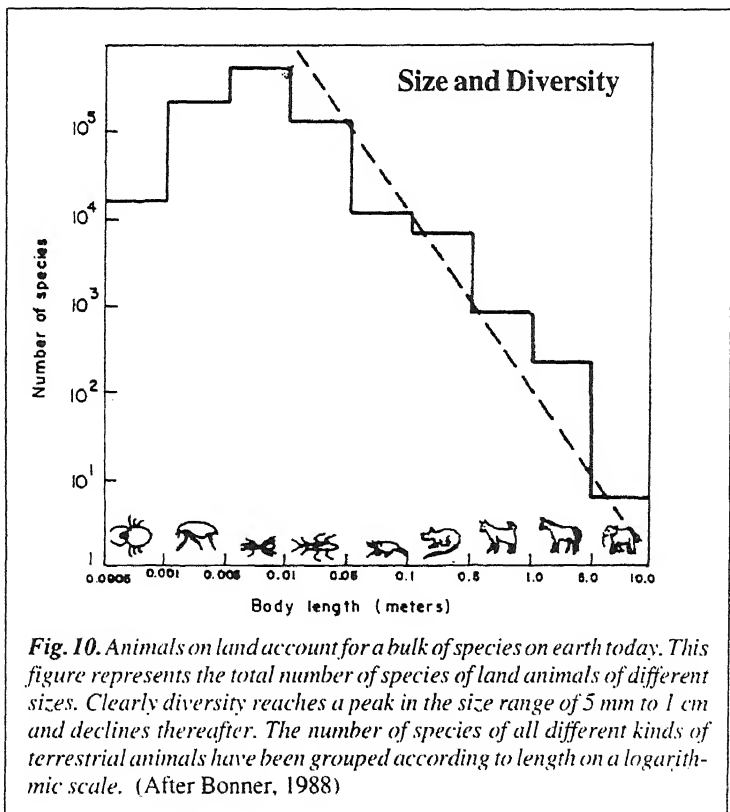


All humans constitute one species, all tigers another, all lions a third. Although lions and tigers may be interbred in zoos, they never do so in nature, and :therefore deserve to be considered as separate species. To prevent the extinction of mega-fauna such as the lion it is vital that the ecosystems which support them are protected. In the process all plant and animal species, including mosses, fungi, lichens and termites receive protection.



Light is a key resource, with plants becoming locked in a race for light. They thus produce more and more structural matter and grow taller and taller, some finally reaching gigantic proportions. The relationship between plants and animals is one vital key to the diversity of life on earth.

environments, light becomes the key resource, and plants get locked in a race for light. So they produce more and more structural matter and grow taller and taller, finally reaching the gigantic proportions of a redwood or a banyan tree. In the dry environments, the advantage lies with the plants that can use water most economically. Desert plants have evolved a more complex form of photosynthesis that permits them to postpone having to take in carbon dioxide till nighttime. Thus they can keep the leaf



pores closed during the hot hours of the day and thereby cut down on water requirements.

Feeding on other plants and animals locks many animals into a contest with their victims. While the victims continually evolve new ways to foil predators, the predators evolve to overcome these defences. Antelopes become ever fleet of foot, cheetahs evolve to run faster. While rhinos and elephants evolve a large size and thick hides, lions and tigers get to be large enough to tackle the young, if not full grown adults of these species. In the rain forest, lush green leafy matter is consumed by a myriad insects. Rainforest plants produce a whole range of toxic chemicals to counter this threat. In turn the insects evolve means of neutralising these poisons. It is this chemical warfare that is responsible for the evolution of the many, many valuable drugs that humans extract from the plants of the humid tropics.

Mutual aid

But animal, plant and microbial species do not only subsist at the cost of each other. They often help each other. Indeed some of the most attractive manifestations of life, colourful flowers and delectable fruit have evolved in the context of mutual help.

The early land plants relied on wind and water to carry pollen and disperse seeds. But the operation of these physical factors is a matter of chance. So the plants evolved flowers to attract pollinators, to reward them with a sugary nectar. Pollen will be wasted if deposited onto a flower of a different species. Therefore plants have developed flowers of distinctive sizes, shapes, colour patterns to ensure that a pollinator would move on to another flower of the same species. They have also specialized in being served by a particular type of pollinator. The bright red flowers of the silk cotton tree attract jungle mynas with their pollen brush

of modified feathers over their beaks, and sunbirds insert their slender, curved beaks into the tubular flowers of mistletoes. Honeybees visit the blossom of jamun, and night-flying moths that of the night queen (*raat ki rani*).

Plants have also developed fruits whose flesh rewards animals for dispersing their seeds. Again there are a myriad specializations directed at many different animals. Mangoes hang on long stalks to facilitate bats plucking them, while sandal berries attract bulbuls. There are other intricate mutualisms as well. Very few living organisms can produce chemicals capable of breaking down the tough molecules of cellulose.

But certain microorganisms can and animals like cattle and deer have elaborated special chambers in their guts to lodge these helpers. And on coral reefs fishes are found which specialize in ridding other fishes of parasites growing on their bodies.

Packing species

Thus life has gone on expanding over its three-and-a-half-billion-year history on the earth, ever elaborating larger and more complex organisms. But the bigger, more complex organisms have added on to and not replaced the smaller and simpler ones. Thus when a branch of a giant banyan tree (one of the largest, most complex of all creatures) is snapped in a storm and begins to rot, it nourishes decomposing bacteria which are amongst the simplest, smallest of creatures. The history of life has therefore been a process of continual increase in the variety of life. It is a process that feeds on itself. The banyan tree is one of a group of strangler figs—trees that are adapted to begin their life on top of other trees. Only after other trees have formed a forest canopy could such stranglers have evolved. Growing in litter accumulated in crevices and hollows on host trees, the strangler figs are freed from the

compulsion to produce seeds for germination in a restricted season, such as at the beginning of the monsoon. So unlike most other tree species, figs have evolved to fruiting at all times of the year. This requires pollinators the year round. Since there would be few other trees to pollinate in the general off-season, figs need specialized pollinators. A special group of insects, the fig wasps, have evolved to fill this role. There is a whole diversity of such fig wasps, often a separate species specialised to a given species of figs. The fact that figs fruit throughout the year greatly improves the availability of fleshy fruits in the tropical forest habitats. This is especially significant in months when almost no other fleshy fruit are being produced. Figs help monkeys and fruit-eating birds like barbets and fruit pigeons tide over such lean periods, thus aiding the evolution of many animals specialized on fruit diets. In turn fruit-eating animals support many, many species of parasites. These are often specialized to live on or inside the bodies one particular species of host. Some of these parasites, such as hair lice, have their own specialist parasites: bacteria, viruses and fungi.

"That figs fruit throughout the year greatly helps monkeys, barbets and fruit pigeons."

Species turnover

Thus, the diversity of living organisms has gone on exploding, hand in hand with the complexity of interaction amongst organisms in biological communities. In the dance drama of life the plot becomes ever more intricate, calling continually for new roles, recruiting increasingly more players. And there are many such dances in all corners of the earth, adding yet another dimension to diversity of life. Thus redwhiskered bulbuls replace redvented bulbuls as one goes from drier into moist woodlands. And different species of snails walk up a beach in the zone where tides

wash back and forth. Along all gradients where the environment changes, for instance, from moist to drier conditions, as one goes away from a riverbed, or from a region of higher rainfall to one of lower rainfall, the set of species changes. The same is the case as one goes from a warmer to a cooler region, for instance up Himalayan slopes, or northwards in India from Kanyakumari to Kashmir. These changes occur because any given species is best adapted to a specific environmental regime, and is replaced

“Geographical turnover is yet another reason for the variety of living organisms on earth.”

by a better-adapted species as the regime changes. Ecologists term this component of diversity species turnover. The term species packing is used for the diversity of a large number of species occurring together in the same community.

There is yet another reason for the variety of living organisms on the earth, and that is geographical turnover. India, for example, has two species of wild goats or tahr that inhabit the rocky crags of high hills. The southern Western Ghats harbour the Nilgiri tahr, while another species of the same genus, the Himalayan tahr lives in the Eastern Himalaya. The Indian continent supports three species of macaque monkeys; the bonnet macaque south of the Godavari river, the rhesus macaque north of Godavari and the Assamese macaque in the Brahmaputra valley. Islands tend to evolve their own sets of species, a witness to the fact, being the birds, Narcondam hornbill and Nicobar megapode, and the coconut crab restricted to the Andaman & Nicobar Islands.

Diversity within a species

The diversity of life may be viewed at many different levels. It may be viewed at the level of hereditary material, as molecules of nucleic acid that carry the instructions for conducting most of

the business of life. Living organisms reproduce in two different ways; with or without sexual union. Most higher organisms reproduce sexually, through coming together of egg and sperm cells. Each egg cell and each sperm cell tends to carry only half the hereditary material of the parent, and all sex cells are different from each other. As a result every individual formed through their union is also unique. There are many, many billion individuals produced through sexual reproduction on earth at any time. Each one of them is in some way different in its hereditary constitution from the other. The extent of variation is somewhat circumscribed in species that are not such products of sexual reproduction. For instance, when a bacterial cell splits into two, both cells may carry identical hereditary material. Or when a curry leaf tree, or an Indian cork tree produces new plants from root sprouts, the daughter plants may be identical in their heredity to the mother plants. In very special cases, as that of identical brothers or sisters in our own species, even sexually produced individuals may carry identical hereditary material. But these are rare exceptions.

"A mother and a daughter, at the very minimum share half their hereditary material."

Almost every sexually produced individual is different from every other in some detail of its hereditary material. But two such individuals may also be similar in many, many details. Indeed a mother and a daughter, at the very minimum, share half their hereditary material. If the husband and wife shared some traits, as they often would, then the mother and daughter would share much more than half of their hereditary material. Sets of individuals would indeed thus have much genetic material. Such a set, for instance, is all human beings, or all bonnet macaques, or all domesticated donkeys, or all banyan trees. Having much in common, such individuals are potentially capable of reproduc-

ing with members of the opposite sex within the set. These constitute what biologists call species. Generally members of a species are fertile and may breed with each other under natural conditions. So all humans constitute one species, all tigers another, all lions a third. Although lions and tigers may be interbred in zoos, they never do so in nature, and therefore deserve to be considered as separate species. On the other hand, white Europeans, black Africans, Mongoloid Orientals, and

“DDT no longer kills mosquitoes in many parts of India... they carry resistant genes.”

African aborigines, are all perfectly inter-fertile and are clearly members of the same human species. The diversity of life is therefore best viewed in two major contexts; the diversity of hereditary material amongst members of the same species and the diversity of species within a biological community, or in any specific region such

as the Indian subcontinent.

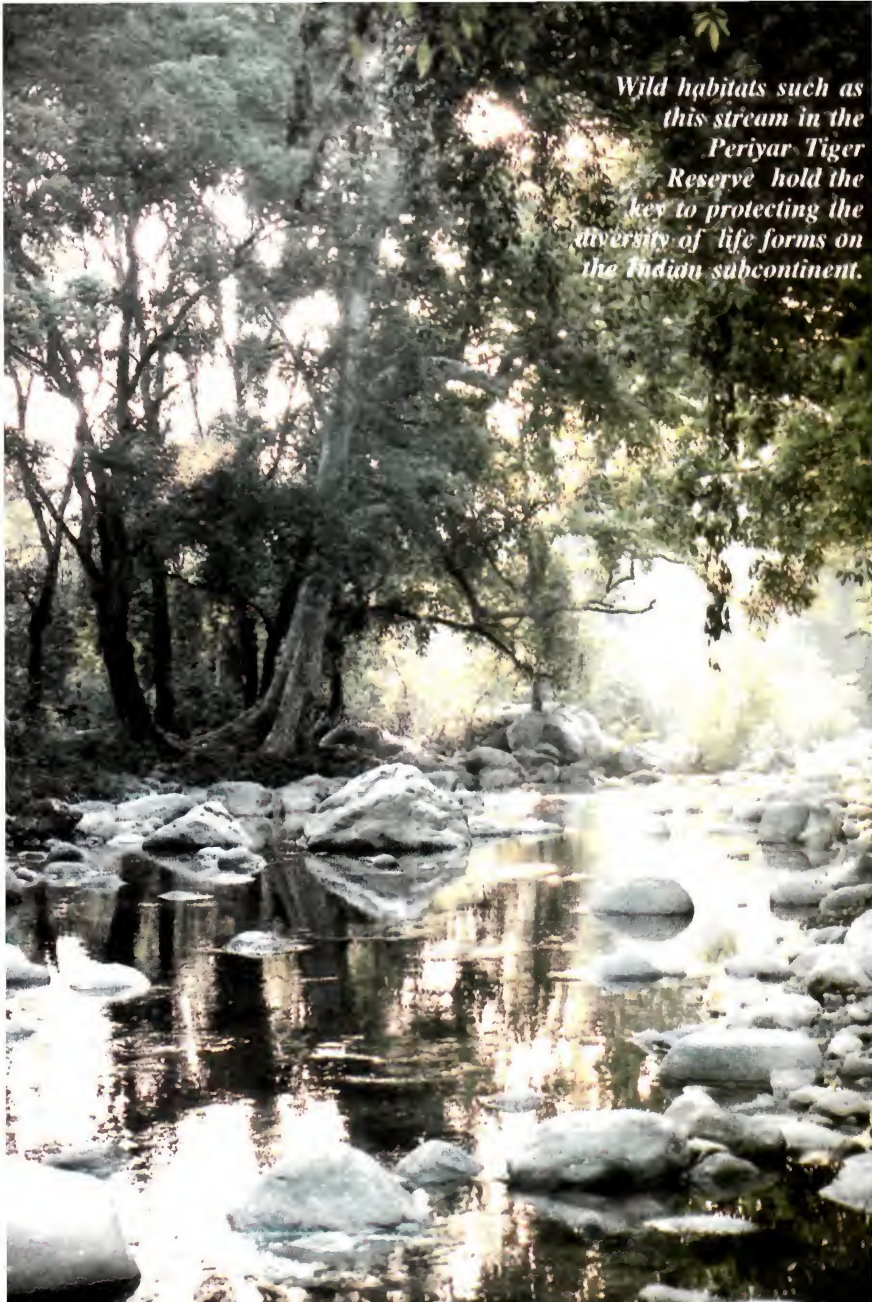
Recent discoveries of the chemical nature of hereditary materials have revealed considerable information on the extent of variation amongst members of the same species. The hereditary material of any individual is made up of several thousand to several hundred thousand units or genes. There is no variation whatsoever for 60 per cent to 80 per cent of these genes; they are identical in all members of any species. Several forms occur for the remaining 20 per cent to 40 per cent of the genes. Every individual in a sexual species carries two sets of genes, one derived from the mother, the other from the father. Between five per cent to 14 per cent of these two sets of genes are in more than one form; for instance the mother having contributed a gene for brown eyes and the father for black eyes. This diversity within species is of great significance as the raw material for all evolutionary change. For instance, DDT no longer kills mosquitoes in many parts of India.

This is because the mosquito species contained individuals with genes that permitted the bearers to withstand exposure to DDT. Before DDT came into common use there were very few individuals carrying such genes. But once DDT began to be sprayed on a large scale such individuals were at a great advantage. They survived while mosquitoes bearing other genes that rendered them susceptible to DDT were killed. So gradually the proportion of mosquitoes with genes conferring DDT resistance continued to increase and now most Indian mosquitoes are DDT resistant. The tremendous diversification of life from a single origin three and half billion years ago till today is ultimately based in such evolutionary change for which genetic variation within species has provided the basic raw material.

“Genetic variation within species was the raw material for evolutionary change.”

So much for variation within a species. Higher levels of differences in the hereditary material mark one species from another. Where they are closely related, as in the case of humans and chimpanzees, much of the hereditary material is held in common. Thus, humans and chimps have about 98.4 per cent of the same genes, although the exact form of the genes would differ for a much larger proportion.

We share about 97.7 per cent of the genes with gorillas, 96.4 per cent with orangutans, and 93 per cent with other Old World monkeys. But even very, very different organisms such as green plants and mammals have a proportion of widely shared genes – take for instance the gene coding for the production of a protein called Histone H4 involved in binding nucleic acids. This protein differs in only two out of a hundred amino acids in organisms as different as the pea plant and cattle.



*Wild habitats such as
this stream in the
Periyar Tiger
Reserve hold the
key to protecting the
diversity of life forms on
the Indian subcontinent.*

Apart from the destruction of wild habitats, poaching serves to devastate diversity by targeting specific species. The tiger has been thus targeted and we now lose up to one tiger a day to poachers. This skin hangs out to dry in a village next to the Kamlang Sanctuary which adjoins the Nandapha Tiger Reserve in Arunachal Pradesh.





This Impatiens nilagirica bloom represents one of the most aesthetic aspects of India's biodiversity. Several insect forms would die out if these flowers were to vanish on account of poor land management in the Nilgiris.

Diversity across species

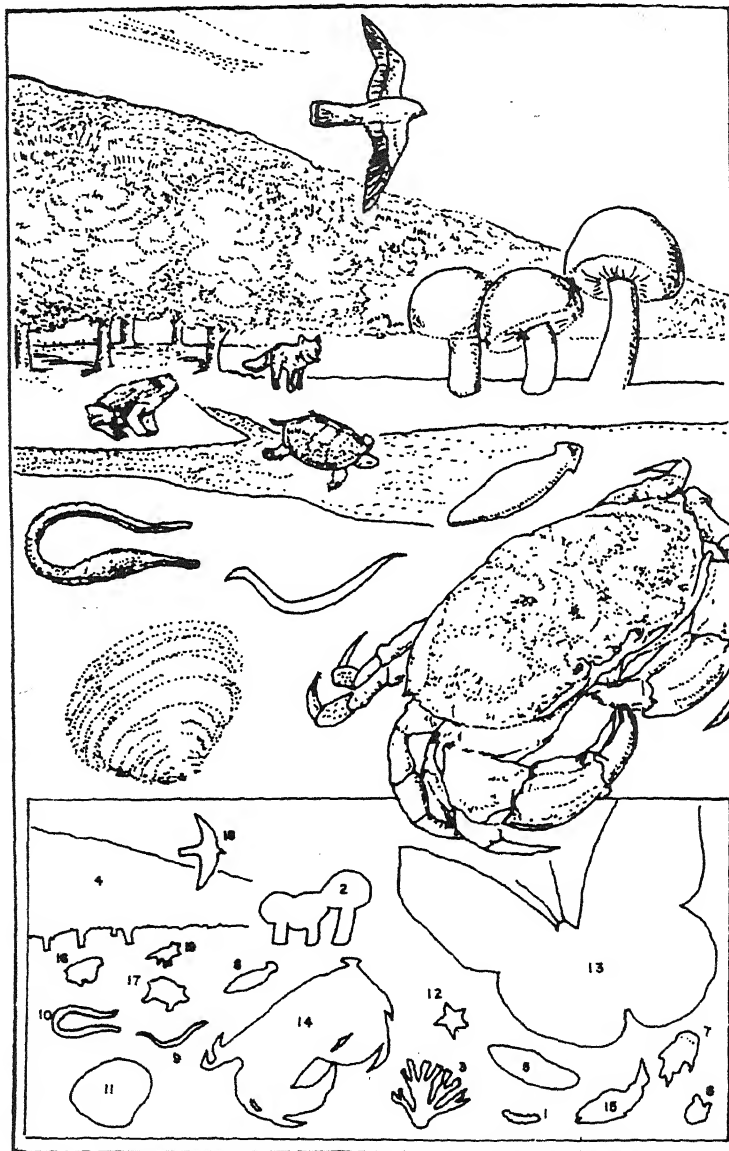
The most striking aspect of diversity around us is that of different kinds of species of living organisms: the viruses that we cannot see, released however with every sneeze, the bacteria, also invisible to us, that we drink with every glass of buttermilk. The mould that grows on rotting fruit and the mushrooms that grow on decomposing logs of wood. The banyan trees that line our avenues, the fig wasps that live inside the fruit of those trees and

“One can only speculate on the total number of species on the surface of the earth today.”

the crimson-breasted barbets and koels that feed on these fruit. So how many different species of living organism exist? What we know for sure is that about a million-and-a-half have been described in scientific literature to date. A quarter of a million of these are plants, over a million are insects and spiders. Only 4,000 differ-

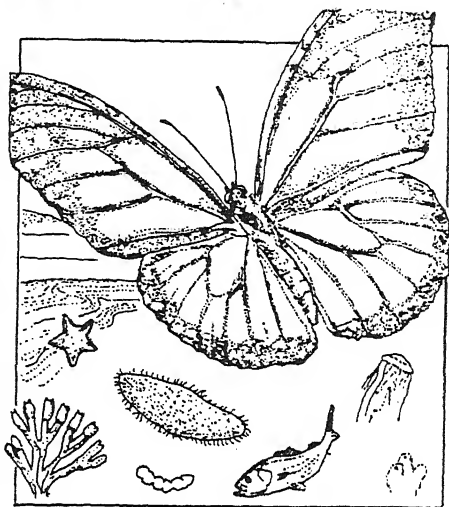
ent species of bacteria and 5,000 species of viruses have been described. There are 45,000 described species of vertebrates – fish, frogs, snakes, turtles, birds and mammals all put together. There are almost an equal number, 40,000 described species of crabs, shrimps and related crustaceans.

Every day a new species is being discovered and described. Many of these are small insects a few millimetres in size living in the canopy of tropical forests. It is speculated that there may be as many as ten to fifty million species of such insects that are still unknown to science. Most of the vertebrates have probably been already described, and perhaps only another 5,000 or so remain to be added to the known list of 45,000. So one can only speculate on the total number of species on the surface of the earth today. Very likely it is around 15 million, ten times the number of described species. But it could be 100 million!



The Species-Scape

Fig. 11. There is a tremendous variation in the number of species belonging to different groups of organisms, and this variation is indicated by the relative sizes of different organisms in the figure opposite. As there are many more species of insects and crabs and their relatives, these loom much larger in the species-scape than do fishes or frogs.



The size of the representative organisms in each group has been made to roughly proportional to the number of species currently known to science. The code and number of species are given below. Viruses and some minor invertebrate groups have been omitted. (After Wilson, 1992)

- | | |
|---|---|
| 1. Monera (bacteria, cyanobacteria), 4,800 | relatives), 12,000 |
| 2. Fungi, 69,000 | 11. Mollusca (mollusks), 50,000 |
| 3. Algae, 26,900 | 12. Echinodermata (starfish and relatives), 6,100 |
| 4. Higher plants, 248,000 | 13. Insecta, 751,000 |
| 5. Protozoa, 30,800 | 14. Non-insectan arthropods (crustaceans, spiders, etc.), 123,400 |
| 6. Porifera (sponges), 5,000 | 15. Fishes and lower chordates, 18,800 |
| 7. Cnidaria and Ctenophora (corals, jellyfish, comb jellies and relatives), 9,000 | 16. Amphibians, 4,200 |
| 8. Platyhelminthes (flatworms), 12,200 | 17. Reptiles, 6,300 |
| 9. Nematoda (roundworms), 12,000 | 18. Birds, 9,000 |
| 10. Annelida (earthworms and | 19. Mammals, 4,000 |

Hotspots of diversity

All parts of the globe are obviously not equally rich in the diversity of life. On land the tropics are far more diverse, on the sea bottom the cold, unchanging depths of oceans are especially rich. Malaysia and Norway have almost identical geographical areas of around 32 million ha; roughly 10 per cent of India's. But while Malaysia has 12,000 species of higher plants, Norway has only 1,600. Malaysia has 158 species of frogs, salamanders and their relatives; and 268 species of reptiles. Norway on the other hand has only 5 species of each group. Malaysia has 501 species of birds and 264 species of mammals and Norway is home to 264 species of birds and only 54 of mammals. The much greater variety of tropical life has been attributed to a variety of reasons; greater productivity, year-round occurrence of conditions favourable to life, lower levels of impact of ice ages in the geological past. All these factors have led to higher levels of species packing in the tropical latitudes.

*"Australia has
the largest
number of
endemic species
in the whole
world."*

Species turnover or the replacement of one set of species by another is the second component of species diversity. Species turnover levels are particularly high where environmental regimes change rapidly as at the seashore. In terms of broader land regions, mountain tracts are apt to have high levels of species turnover. This explains why mountainous tracts like our own Western Ghats and Eastern Himalaya as well as the Eastern Arc Mountain of Tanzania figure among the world's "hot spots" of biological diversity.

An excellent measure of geographical turnover, the third component of species diversity is the proportion of species unique to a

Biological Treasure Troves

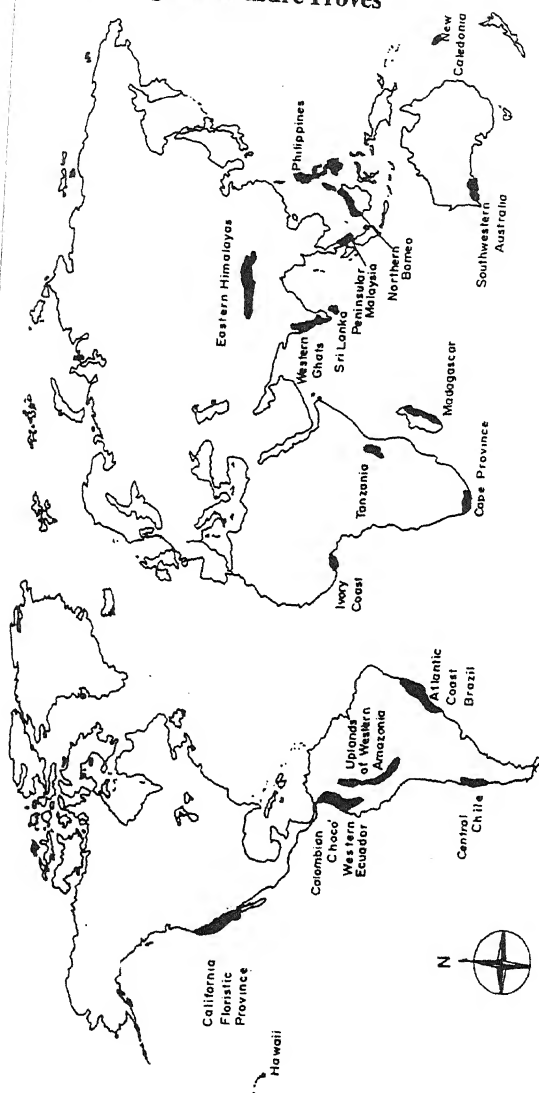


Fig. 12. Eighteen "hot spots" have been identified as regions on land that harbour a large number of species exclusive to the region and in great danger of extinction from the impact of human activities. This identification is however far from complete, and focuses on forests and Mediterranean scrublands and leaves out lakes, rivers and coral reefs. The Indian subcontinent includes two of these hot spots, namely, the Western Ghats and the Eastern Himalayas. (After Wilson, 1992)

region. Such species, restricted to a given region are said to be endemic to that region. Islands by virtue of their long isolation are especially rich in endemic species. Australia leads all countries of the world in the number of endemic species of mammals (210) and reptiles (605). Australia is next only to Indonesia, another island nation, in its number of endemic birds (349). Indonesia in turn is second in the world in the number of endemic mammals (165), leading all other countries in the number of endemic birds (356). The island of Madagascar has 67 endemic species of mammals, 97 endemic species of birds, 231 endemic species of reptiles and 142 endemic species of frogs and their relatives. Compare this with India, five times as large in land area, with 38 endemic species of mammals, 69 endemic species of birds, 156 endemic species of reptiles and 110 endemic species of frogs and their relatives.

***"India has 389
species of
reptiles; of
which 156 are
found nowhere
else."***

A country of megadiversity

On the world stage, India is one of the richest nations in terms of biological diversity. We owe this to India's position in the tropical and subtropical latitudes with their inherent wealth of life. Also to the mountain chain of the Himalaya that has created a great range of environmental regimes on the northern border. And of course to the Thar desert that has created another gradient of rapid environmental change in the northwest. We also owe this diversity to our possession of islands like the Andaman & Nicobar and Lakshadweep with their own sets of endemic species, and to India's position near the tri-junction of Eurasia, Southeast Asia and Africa. India has therefore been christened one of the world's top twelve megadiverse nations.

India supports 15,000 species of flowering plants, 5,000 of them

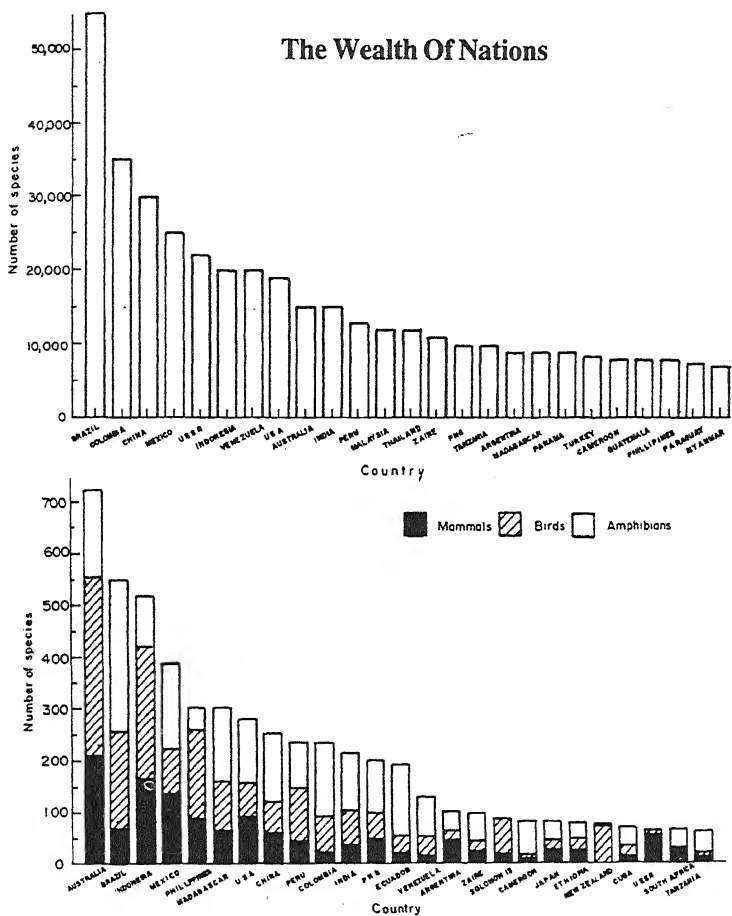


Fig. 13. The diversity of living organisms is not evenly distributed on the earth. Humid tropical habitats tend to be particularly rich in the total number of species present in any given locality. Islands, on the other hand, tend to have a larger proportion of endemic species; i.e. species that do not occur elsewhere. The figures above indicate the total number of species of flowering plants and of endemic reptiles, birds and mammals in the 25 best-endowed countries of the world. India ranks tenth and eleventh on these two criteria. This is why India has been identified as one of the top 12 mega-diversity countries in the world. (After World Conservation Monitoring Centre, 1992)

exclusive to us. In comparison Brazil, the world's most biologically diverse nation has 55,000 species of flowering plants and amongst our Asian neighbours China has 30,000 and Indonesia 20,000. India has 317 species of mammals, 38 of them exclusive to us. Indonesia leads the world with 515, 165 of them endemic, with both China and Brazil having 394 each. India has 969 species of birds, 69 of them endemic. The Central American nation of Colombia leads the world with 1,721 bird species Indonesia has 1,519 and China 1,100. India has 389 species of reptiles, 156 exclusive to us, Mexico leads the world with 717, 368 of them endemic; and as many as 616 of Australia's 700 species of reptiles are exclusive to that island continent. Of our Asian neighbours, Indonesia has 511 and China 282 species of reptiles. India scores relatively high in terms of frogs, salamanders and their kith and kin. We have 206 species of amphibians, 110 of them endemic. Brazil of course is way ahead with 502 in this category of which 294 are endemic. Indonesia has 270, with 100 endemics and China 190 with 131 endemics.

“Genetic variation within species was the raw material for evolutionary change.”

In the matter of biodiversity, India stands quite high in the wealth of the total number of living species; although not at the very top. Overall, we stand closer to tenth in the pecking order of nations. This diversity of species is not evenly distributed within the country. Some parts are especially rich due to a variety of natural causes; others less so. Some parts have also been secondarily enriched, or more often impoverished, by human intervention.

As mentioned earlier two of India's great mountain ranges, the Eastern Himalaya and the Western Ghats have been designated among the world's eighteen “hot spots” of biodiversity. They

India also shares many of the species endemic to the Eastern Himalaya with other countries, especially Nepal, Bhutan, China and Myanmar. From that perspective then the Western Ghats, whose species are shared only with Sri Lanka, are the country's most significant region in terms of biological diversity.

The Andaman & Nicobar Islands are the third most significant area of biodiversity in India, with 144 species of flowering plants and 75 species of land snails that do not occur anywhere else in the world.

Spasms of extinction

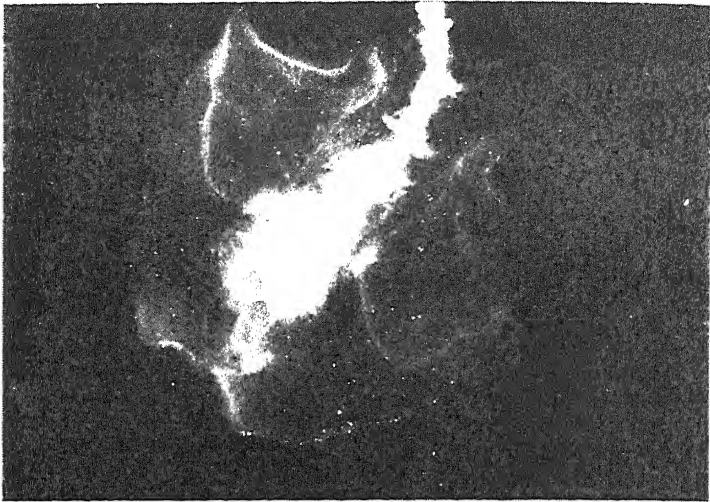
The evolutionary history of life is one of continual expansion, where living organisms exhibit greater diversity in a cosmic dance that has become ever more elaborate as it inducted more and more actors into its fold. Of course, change including extinctions of species has been endemic to the drama of evolution. Life has experimented with an enormous number of designs, discarding most of them however. This slow, continual pace of extinction and replacement has gone hand in hand with an on going, overall increase in diversity. This smooth ascending curve has also been interrupted from time to time, as if Kali has stepped in to clear the evolutionary stage and create a fresh beginning.

"The earth is set to lose between one and ten per cent of all living species."

The most massive of such episodes occurred 245 million years ago, at the boundary of the Permian and Triassic periods of geological history. At that time as many as 96 per cent of species of marine animals seem to have been wiped out. There have been four other major episodes of extinction in geological history, although none as severe as the one that took place 245 million years ago. The latest of these episodes dates to 65 million years ago, when the dinosaurs were wiped out. These dramatic

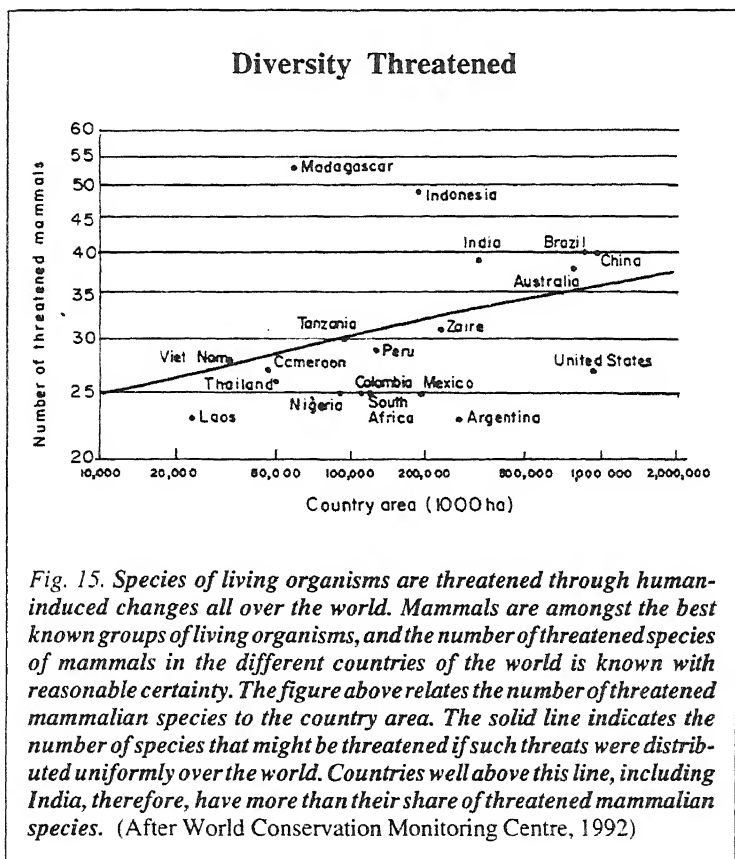


While "food" is something city folk buy, it means something completely different to ecosystem people. Wild foods have been and will continue to be the mainstay of millions of men, women and children on the Indian subcontinent. Protecting this diversity, which includes nuts, roots, tubers and fish is essential to the protection of our national food security.



The race to patent lifeforms including microorganisms has lent new urgency to the need for India to document its own natural wealth. With cures ranging from cancer to AIDS awaiting discovery, the study, protection and appreciation of diversity becomes more crucial than ever before.

episodes of mega-extinctions were probably due to some geological convulsion; either a hit by an enormous asteroid or a major volcanic eruption. Barring such episodes of extinction, background extinction rates are estimated as being around one species of mammal every 400 years or one species of bird every 200 years. The last few centuries have witnessed dramatic increases in these rates, however not due to geological convul-



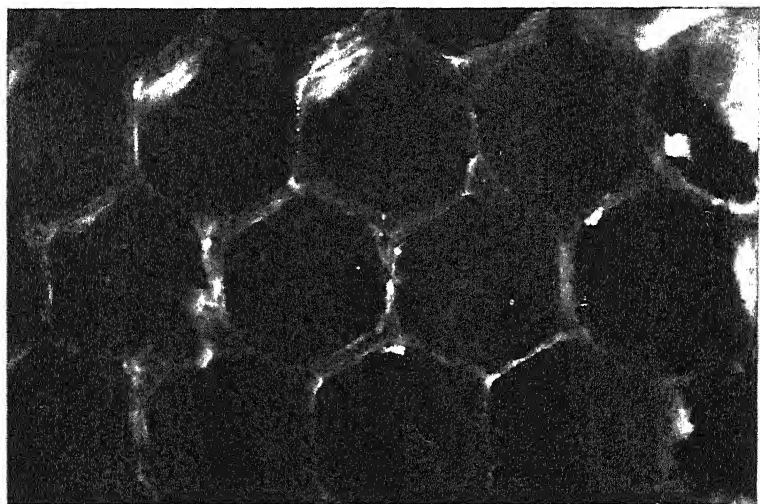
sions, but on account of the entry of the most complex of living organisms ever to have made an entry on the evolutionary stage – *Homo sapiens*.

Agents of destruction

Human beings indeed deserve to be considered the most complex of living organisms. This is because complexity resides in the diversity of linkages amongst the manifold components of any system. All higher plants and animals are made up of units called cells. Simplest organisms like sponges or mushrooms have just a few kind of cells, more complex organisms like crabs or frogs have tens of different kinds of cells. These cells relate to each other in many different ways; the most advanced of these is through connections of nerve cells. Each nerve cell has many processes, which connect, to other nerve, muscle or gland cells. Our brain is of course a bundle of millions of nerve cells, and these can connect to each other in many different ways depending on the conditions to which each of us is exposed. It is this diversity of possible linkages of nerve cells that has conferred on humans an exceedingly high level of complexity. It has also conferred on humans an ability to learn, to adjust their behaviour, to fabricate tools, to deliberately modify their environment. And this deliberate environmental modification has involved creating conditions that favour a small number out of the immense diversity of living species, resulting in a reversal of the evolutionary trend to continually increase the total diversity of living species.

“Genetic variation within species was the raw material for evolutionary change.”

With humans dominating the scene the rate of extinction of species has far exceeded the rate of origin of new species. Over the last three centuries 115 species of birds and 58 species of



The diversity around us has more uses than one might imagine. Aeronautical engineers, for instance, figured out how to make helicopters after studying the dragonfly. The tensile strength of spider's silk is still the envy of most structural engineers. And architects long for the ability to replicate the perfection and economy of the hives crafted by 'lowly' honeybees.



If the forests of India continue to be abused as they now are, the human race will lose uncounted diversity. The North Indian red junglefowl, for instance, gave rise to the domestic chicken. Several species of legumes, such as chick pea and green gram, oil seeds like sesame, spices like pepper and cardamom, and fruit like mango and jackfruit are other significant contributions of India to the global stock of genetic diversity of husbanded plants and animals. Can we allow these to be lost to the world?

Nurturing Diversity

CENTERS AND DIFFUSE AREAS OF ORIGIN OF CULTIVATED PLANTS

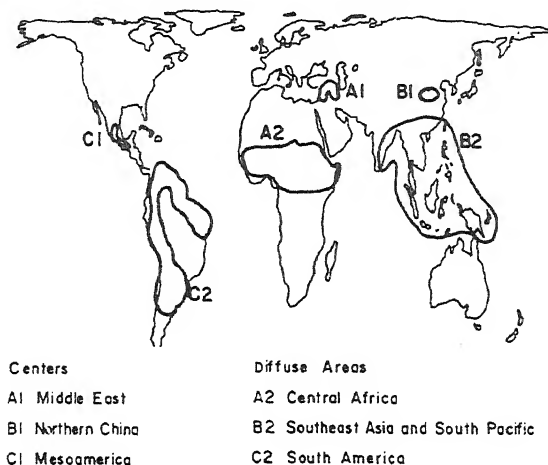


Fig. 16. While humans have destroyed the diversity of life, they have also promoted it, albeit in a limited number of species of plants and animals brought under domestication. Amongst the oldest of such domesticated creatures is the dog and it is human beings that are responsible for the marvellous range of dog breeds, from the tiny Pomeranians to the giant Saint Bernards. The mango occurs in the wetter forests of the Indian subcontinent. Humans have extended its distributional range in the wild; it is also extensively cultivated. Consequently the genetic diversity of the mango has undoubtedly been greatly enhanced. Plants and animals have been brought under domestication by humans in a few major centres in the world, the Middle East, and the Mesoamericas being amongst the most important of these. The Indian subcontinent has served as a secondary, yet significant centre of domestication of a number of species of plants and animals. Rice and water buffalo might have been brought under domestication in India, although China and Southeast Asia too have claims as the possible centres of origin of these important species. The humped zebu cattle were domesticated in India, although several centuries after the original domestication of cattle in the Middle East. Yak and mithun, two species allied to cattle were domesticated in the Western and Eastern Himalayas. The North Indian red junglefowl gave rise to the domestic chicken. Several species of legumes, such as chick pea and green gram, oil seeds like sesame, spices like pepper and cardamom, and fruit like mango and jackfruit are other significant contributions of India to the global stock of genetic diversity of husbanded plants and animals.

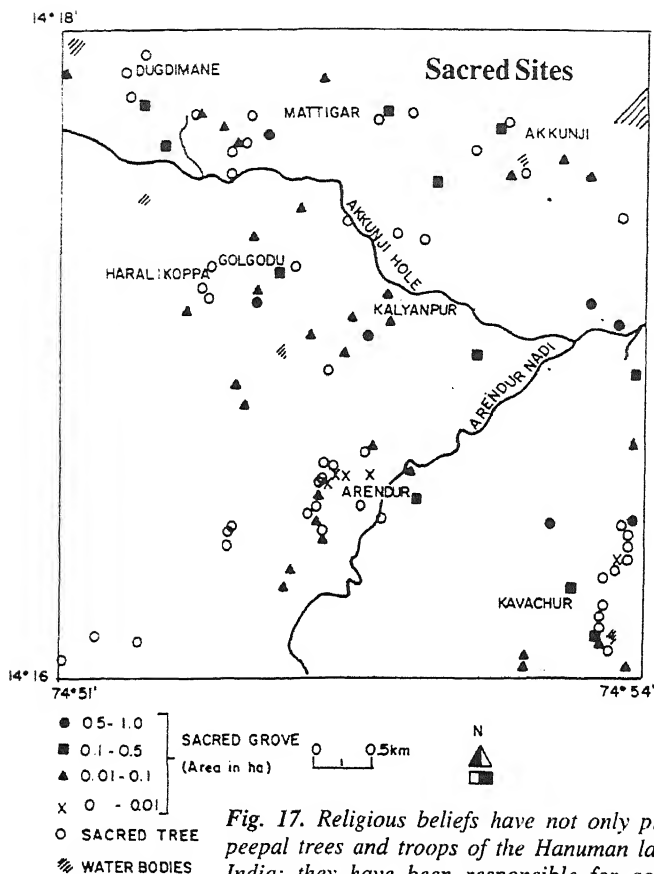
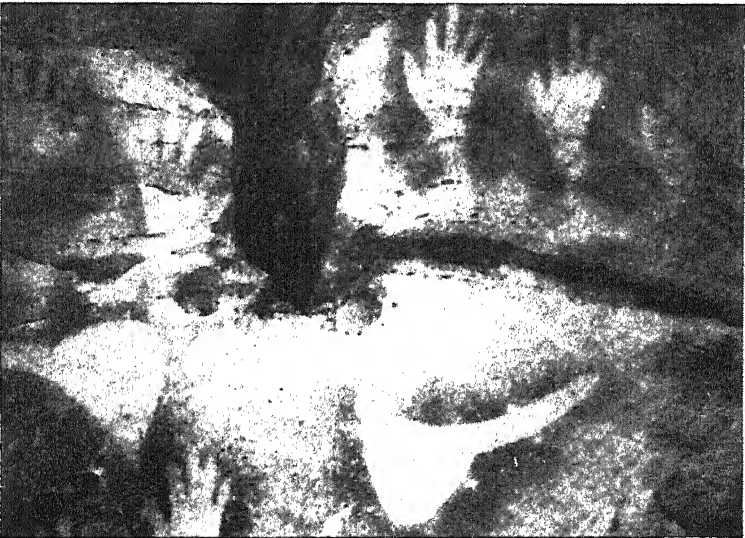


Fig. 17. Religious beliefs have not only protected peepal trees and troops of the Hanuman langur in India; they have been responsible for according protection to entire biological communities in the form of sacred groves and sacred ponds. Such sacred groves and ponds once covered much of the world; they persist today in a more attenuated form, in Asia, Africa, Australia and America. All parts of the Indian subcontinent harbour fragments of pristine biological communities in such sacred sites. In densely populated Bangladesh the only surviving population of a turtle species, *Trionyx nigricans*, lives in a pond sacred to a Muslim saint called Byazid Bostami. In the equally populated plains of Kerala, botanists discovered in a sacred grove a hitherto unknown genus from India, and described a new species *Kunstleria keralensis*. A study of a 25 km² region from Karnataka, Western Ghats, has shown that even today 0.3 per cent of land in this region is covered by a total of 50 sacred groves harbouring many species characteristic of undisturbed rain forests of this forest tract.



The wisdom of the years speaks out from stone in the shape and form of ancient Sanskrit etchings. The knowledge of the past, serves much more than historical purposes. The messages left for us in stone could probably help us discover ways to live with the flow of nature rather than flail against its powerful tide.



Around the world in continents as diverse as Asia, Africa, Australia and the Americas, entire biological communities in the form of sacred groves and sacred ponds have received protection from traditional people. Totems represent a respect for nature and its power. Sacred qualities are often ascribed to springs, mountain peaks, plants and animals which are closely protected.

mammals are known to have become extinct. This is a considerable number, greater by a factor of 50 times than the background rates that prevailed during geological times. But even this increase of extinction rates by a factor of 50 is nothing compared to the loss of diversity we are likely to experience in coming years. For the earth is all set to lose somewhere between one and ten per cent of all living species over the next decade.

The Conservation ethic

Human beings are then by far the most destructive species that biological evolution has so far produced. But humans are also the only species capable of consciously understanding its impact on nature and of taking appropriate action. And it is very much to the credit of human beings that they have time and again striven to protect, and even to enhance the diversity of life on earth. Respect for nature permeates all primitive peoples. While they must and do destroy living organisms in their efforts to make a living, they tend to be careful not to destroy unnecessarily. They also ascribe sacred qualities to springs and mountain peaks, and plants and animals, protecting them closely.

When hunting and gathering was supplemented by shifting cultivation, people tended to create a mosaic of different stages of forest vegetation, leaving patches of sacred forests in their primeval state. This must have greatly enhanced diversity of life on a local scale. Having taken to cultivating plants and domesticating animals, primitive cultivators and herders help create enormous diversity of genes within the species favoured by them. India, for instance, had no less than 30,000 different local varieties of rice in cultivation till 30 years ago, along with a wide range of minor millets, pulses, oil seeds and leafy, green vegetables.

As people advanced to more stratified agrarian societies, rulers supplemented the folk practices of conservation by setting aside hunting preserves. Finally, in more recent decades, states have established protected areas dedicated to nature conservation; wildlife sanctuaries, national parks, biosphere reserves.

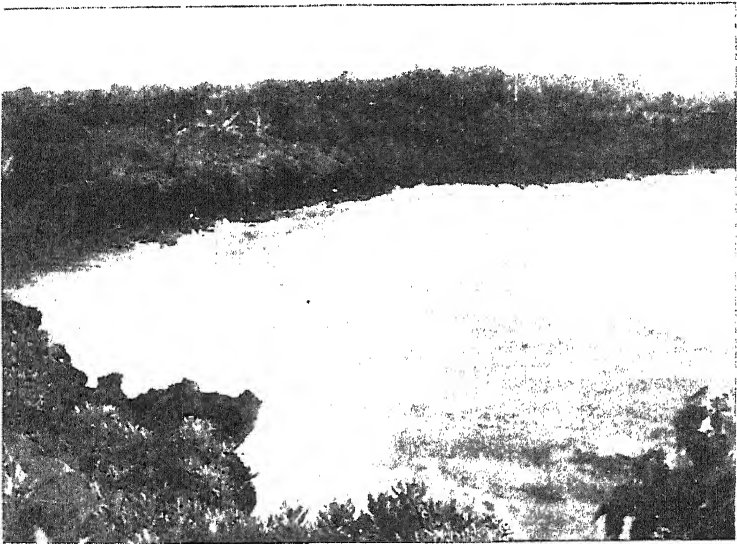
India's genius

India is a land not only of great biological, but also of great cultural diversity. Our country supports hunter-gatherers on the Sentinel Islands in the Andaman & Nicobar Islands, shifting cultivators in Manipur and Nagaland, nomadic sheep keepers in Rajasthan and Himachal Pradesh, Green Revolution farmers of Punjab and Haryana, artisanal fisherfolk of Chilika and purse seiners of Goa, reed weavers of Kerala and the citizens of industrial metropolises of Mumbai and Chennai.

The genius of Indian society has woven a rich tapestry of conservation practices with strands derived from its varied cultures. Sacred banyan trees dot the Indian countryside. Peepal trees associated with the many temples are the largest trees to be found in many Indian cities. Troops of macaques and langurs often romp fearlessly around many such temples. Herds of blackbuck, chinkara and nilgai roam around Bishnoi villages in Rajasthan. Sacred groves dedicated to nature deities preserve relict of the primeval rain forest even on the thickly settled plains of Kerala; as they do in the more remote hill areas all over the country. The Asiatic lion was saved from extermination by the Nawab of Junagarh in his hunting preserve of Gir at the close of the nineteenth century. Today it is protected in the Gir National Park. The tiger reserves of Bandipur, Ranthambhor, Sariska, Simlipal, too were princely hunting preserves. The Nilgiri tahr shooting block established by European planters in the upper Nilgiris is today a wildlife sanctuary. And in our homes we let wall

lizards and shrews run around happily.

Ours is an ancient civilization with amongst the highest population densities in the world. It is nevertheless, a land that still retains much of its rich heritage of diversity of life. And this diversity of life is all around us. For us to enjoy, admire, and perchance to revere. All of us can only hope that we will not only continue to



The key to protecting India's biological diversity is respect for ecosystems including coastlines, deserts, forests and wetlands. It is from such natural assets that our diverse cultures and the genius of Indian society originated. From here too will spring solutions to the vexing problems of survival tomorrow.

SOURCES FOR ILLUSTRATIONS

The figures used in this manuscript have been taken from the following books:-

I. World Conservation Monitoring Centre, 1992. Global Biodiversity. Status of the Earth's Living resources. Published by : Chapman & Hall. 1. Page 84, Fig. 8.2. The 25 most plant rich countries. 2. Page 142, Fig. 13.1. Higher vertebrates : the 25 most endemic rich countries. 3. Page 243, Fig. 17.4. Relationship between number of threatened species and country area.

II. Richard Cowen, 1990. History of Life. Published by : Blackwell Scientific Publications 1. Page 7, Fig 1.5. "Universal minimal cell."

III. World Resource Institute (WRI), 1992. Global Biodiversity Strategy – Guidelines for Action to save, study and use Earth's Biotic wealth sustainably and equitably. Published by World Resource Institute (WRI) 1. Page 3, Fig 1. Relative number of described species in major taxa.

IV. Roberts, M.B.V., 1986. Biology – A functional approach (Fourth edition) Published by: English Language Book Society/ Nelson, Thomas Nelson & Sons Ltd. 1. Page 44, Fig. 3.12. Structure of the body wall of the Hydra. 2. Page 280, Fig. 18.17. The basic plan of the vertebrate cranial nerves. 3. Page 291, Fig. 18.25 A. The primitive nervous system of the sea anemone.

V. Solbrig, M.van Emden and P.G.W.J. van Oordt (ed.) 1992. Biodiversity and Global change. IUBS Monograph 8. Published by The International Union of Biological Sciences. 1. Page 87, Fig. 1. The nesting of groups of organisms in relation to niches occupied and evolutionary history, the bacteria in each group being dependent on earlier ones for food & nutrients.

VI E.O.Wilson, 1992. The Diversity of Life. Published by Questions of Science, The Belknap Press of Harvard, Harvard University Press, Cambridge, Massachusetts. 1. Page 138-139, The species scape (Figure). 2. Page 189, Full history of life (Figure). 3. Page 191, Biological diversity (Figure). 4. Page 195, Local diversity of plants (Figure). 5. Page 262-263, Hot spots (Figure).

VII John Tyler Bonner, 1988. The Evolution of Complexity by means

of Natural selection. Published by Princeton University Press, Princeton, New Jersey. 1. Page 8, Fig. 1. A hypothetical evolutionary tree showing the early origins of various major groups of animals & plants. 2. Page 103, Fig. 42. The number of species of all different kinds of terrestrial animals, grouped according to length on a logarithmic scale. 3. Page 123, Fig. 51. A graph showing the size ranges (by weight) of groups of organisms containing different number of cell types.

VIII. Daniel Querol, 1992 Genetic Resources Our Forgotten Treasure. Published by Third World Network, Malaysia. 1. Page 34, Fig. 1.3 Centres and non-centres of origin of plants as proposed by Harlan (1975).

Index

A

- aborigines 29
- Africa 40
- agrarian societies 56
- amino acids 6
- amphibians 43
- Andaman & Nicobar Islands 27, 40, 44
- antelopes 24
- artisanal fisherfolk 56
- Asiatic lion 56
- Assamese macaque 27
- asteroid 47
- Australia 40

B

- background extinction rates 47
- bacteria 16, 26, 35
- Bandipur 56
- banyan tree 23, 25, 35, 56
- barbets 26
- bats 25
- behaviour 48
- Bhutan 44
- big bang 1
- biodiversity 42
- biological community 29
- biological diversity 38, 44
- biosphere 12

- biosphere reserves 56
- Bishnoi 56
- blackbuck 56
- blue green algae 17
- bonnet macaque 27
- Brahma 1
- Brahmaputra valley 27
- brain 48
- Brazil 42
- bulbuls 25

C

- carbon chains 1
- cells 48
- cellulose 20
- cheetahs 24
- chemical warfare 24
- Chennai 56
- Chilika 56
- chimps 30
- China 42, 44
- chinkara 56
- chlorophyll 19
- chondrites 2
- clouds 5
- coconut crab 27
- Colombia 42
- complex molecules 1, 10
- conservation 55
- coral reefs 25
- crimson-breasted barbets 35

crystals 1
cultural diversity 56
curry leaf tree 28

D

Darwin, Charles 12
daughter plants 28
DDT 29
decomposers 16, 17, 18
desert plants 23
dinosaurs 44
diversification 30
diversity 26, 27, 35
diversity of hereditary material 29
diversity of species 29
dung 16

E

Eastern Arc Mountain 38
Eastern Himalaya 27, 38, 42
ecologists 27
egg cell 28
electrical charges 10
electrons 2
elephants 24
endemism 40
environmental modification 48
enzymes 19
Eurasia 40
Europeans 29
evolutionary change 30

evolutionary history 44
extinction 44

F

fig wasps 26, 35
flowering plants 15
flowers 24
fruiting 26
fungi 16, 26

G

genes 29
genetic variation 30
geographical turnover 27
geological history 44
germination 26
Gir National Park 56
gland cells 48
Goa 56
Godavari river 27
gorillas 30
green pigments 17
green plants 17

H

helium 1
hereditary material 27, 28
heredity 11
higher organisms 28
Himachal Pradesh 56
Himalaya 27, 40
Himalayan tahr 27
Histone H4 30

“hot spots” 38
humans 30
hunting and gathering 55
hunting preserves 56
hydrogen 1

I

India 40
Indian cork tree 28
Indian subcontinent 29
Indonesia 40
interfertile 29
iron 1
islands 40
isolation 40

J

jamun 25
Junagarh, Nawab of 56
jungle mynas 24

K

Kali 44
Kanyakumari 27
Kashmir 27
Kerala 56
koels 35

L

Lakshadweep 40
leaf pores 23
lions 24

living organisms 10

M

Madagascar 40
Malaysia 38
mangoes 25
Manipur 56
matter 1
mega-extinctions 47
megadiverse nations 40
megadiversity 40
metals 1
meteorites 1
Mexico 42
microorganisms 25
mistletoes 25
molybdenum 16
Mongoloid 29
mosquitoes 29
mould 35
Mumbai 56
mushrooms 35, 48
mutualism 25
Myanmar 44

N

Nagaland 56
national parks 56
natural selection 12
nebulae 1
nectar 19
Nepal 44
nerve cells 48

new species 35
nickel 1
Nicobar megapode 27
nilgai 56
Nilgiri tahr 27, 56
Nilgiris 56
nitrogen 6
Norcodam hornbill 27
Norway 38
nucleic acids 10
nucleotides 6
nucleus 2

O

Old World monkeys 30
orangutans 30
Orientals 29
oxygen 1, 17

P

parasites 19, 25, 26
peepal trees 56
Permian 44
phosphoric acid 10
photosynthesis 20
photosynthesizers 19
Planet Earth 5
planets 1
poisons 24
pollen 15
pollinators 19
predators 19
prey 19

proteins 12

R

rainforest plants 24
Rajasthan 56
Ranthambhor 56
rate of extinction 48
redvented bulbuls 26
redwhiskered bulbuls 26
redwood 23
reproduction 10
rhesus macaque 27
rhinos 24
root sprouts 28

S

sacred forests 55
sacred groves 56
sandal berries 25
Sariska 56
seashore 38
seeds 25
self-replication 10
Sentinel Islands 56
sex cells 28
sexual reproduction 28
sexual union 28
shifting cultivation 55
silicon chains 1
silk cotton tree 24
Simlipal 56
snails 26
Southeast Asia 40

species 21, 29
species diversity 38
species packing 27
species turnover 27, 38
sperm cell 28
sponges 48
Sri Lanka 44
stars 1
strangler figs 25
sunbirds 25
survival of the fittest 12

T

tahr 27
Tanzania 38
tiger reserves 56
tigers 24
toxic chemicals 24
Triassic 44
tropical life 38

U

urine 16

V

variation 29
vertebrates 35
viruses 26, 35
Vishnu 1
volcanic eruption 47

W

Western Ghats 27, 38, 42

wild goats 27
wildlife sanctuaries 56

KNOWLEDGE IS POWER...



YOU CAN HELP STOP THE SLAUGHTER

1. GET INFORMED...

SUBSCRIBE TO SANCTUARY MAGAZINE

2. GET INVOLVED...

JOIN A CONSERVATION GROUP TODAY!

**For details write to:
The Subscription Manager**

**SANCTUARY ASIA
602, Maker Chambers V,
Nariman Point, Mumbai 400021**

**Fax: 022-2874380, Tel: 022-2830061/81,
E-mail: <admin@ecologist.ilbom.ernet.in>**

JOIN THE BNHS



Today, the BNHS is Asia's premier conservation organisation, with members in over thirty countries and an international reputation as an authority on Asian wildlife.

India's Natural Heritage is in Trouble... Help to Protect it

Membership benefits include:

- A free subscription to *Hornbill*, and concessional subscription for Asia's oldest scientific Journal on natural history. Discount on *BNHS* publications.
- Trips to sanctuaries and national parks at concessional rates.
- Access to India's finest library of wildlife and shikar books.
- The use of *BNHS's* National Heritage Collection of natural history specimens.

READ ALL ABOUT IT!

**What is the Big Bang?
How do plants live in the desert?
What is biodiversity?**



National Council for Science and Technology Communication and the Bombay Natural History Society have collaborated to produce the NCSTC-HORNBILL Natural History Series. Our purpose is to bring the science of natural history to young people. But adults too are sure to relate to these profusely illustrated and authentic sources of natural history information.

Other titles in the series include:
Extinction is Forever by J.C. Daniel
Evolution - the Story of Life by Renee Borges
The Indian Elephant by Ajay Desai
Predators and Prey by Dr. Ullas Karanth
Moths of India by Isaac Kehimkar

Rs. 55/-



ISBN 81-7480-026-3
NCSTC-HORNBILL
NATURAL HISTORY SERIES

